MICROWAVE MEASUREMENTS OF WINDS, WAVES, AND CURRENTS IN THE GLOBAL AND COASTAL OCEAN

William J. Plant
Applied Physics Laboratory
University of Washington
1013 NE 40th St
Seattle, WA 98105-6698
phone: (206) 543-7836, fax: (206) 543-6785, e-mail: plant@apl.washington.edu
Award # N00014-93-1-0016

LONG-TERM GOAL

The long-term goals of this project are to develop and test methods for extracting geophysical information about the coastal and global oceans from active microwave instruments. We ultimately envision the coastal measurements to be made from remotely piloted aircraft and the global measurements to be made from satellites.

SCIENTIFIC OBJECTIVES

The scientific objectives of this research are to understand the interaction of microwave radiation with the ocean surface at a variety of incidence angles and to apply this understanding to extract information about the air/sea interface.

APPROACH

Our approach has been multifaceted. First, we have been utilizing data collected during the SAXON-FPN experiment to extract as much information as possible about microwave scattering from the sea surface and about the imaging of the sea surface by synthetic aperture radars (SAR). Second, we have adapted new techniques for obtaining wind, wave, and current information at sea, which we developed in measurements from an airship, for use on light aircraft. Finally, we have attempted to develop new scattering models that are capable of accounting for both the SAXON-FPN and airborne data.

WORK COMPLETED

This year has been spent working through the backlog of data collected in previous years, attempting to obtain new insight from these data, and submitting the results for publication. Two papers have been published in refereed journals this year. One details the results of our SAXON-FPN SAR studies while the second presents a new model for high-incidence microwave backscatter from the sea. Two more papers presenting results from data collected on the airship have been submitted for publication. A third paper, which shows the importance of the bound waves influences observed in the SAXON-FPN data for the interpretation of backscattering in wave tanks, is nearly ready for submission. Finally, a new, multi-scale scattering model has been developed and coded for the PC. The model is still under development but shows promise of being able to give a unified account of many of the observations from aircraft, towers, and wave tanks.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 1997**	2. REPORT TYPE	3. DATES COVERED **00-00-1997 to 00-00-1997**

4. TITLE AND SUBTITLE **Microwave Measurments of Winds, Waves, and Currents in the Global and Coastal Ocean**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of Washington,Applied Physics Laboratory,1013 N.E. 40th Street,Seattle,WA,98105**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**3**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

RESULTS

The main point of the SAR paper (Plant & Zurk, 1997) is that quasi-linear scattering theory applied to SAR imagery of the ocean having R/V ratios below 70 sec is able to yield good values of observed dominant wave direction and significant wave height. The bound wave paper (Plant, 1997) shows that the strange observations of different Doppler shifts in HH and VV polarized high-incidence-angle scattering from the ocean can be explained on a composite surface model if one assumes that bound waves are produced by meter-length waves on the ocean. In such a case, the Bragg scatterers will be bound to the longer wave and therefore moving with it. Since they will also be tilted, these bound waves scatter at a smaller local incidence angle than other Bragg scatterers when looking into the wind. Since at high incidence angles, a small reduction in angle increases HH backscatter much more than VV, bound wave scattering is more noticeable in HH than VV backscatter. If meterñlength waves become sufficiently steep to produce bound waves only at a certain phase of the dominant wave, then their occurrence can also explain a second, unusual observation of the SAXON-FPN data set. This is the fact that dominant ocean wave spectra cannot be obtained from variations of the Doppler centroid at incidence angles above 70 degrees.

The implication of bound waves in ocean backscatter at high incidence angles was indicated by work in a wind wave tank which showed that the Doppler centroid in the tank occurred at the frequency expected if the principal scatterer traveled at the speed of the dominant wave. We have analyzed this wave tank backscattering in more detail by utilizing measurements of slopes and short wave spectra measured at the same time in the same tank by other investigators to show that indeed scatterers bound to the dominant wave do exist in the tank, are tilted, and can closely explain the behavior of the microwave backscatter observed in the tank. A paper on this topic is nearly ready for submission.

Our airship results have reconfirmed the ability of microwave cross sections of the sea to accurately reflect the behavior of the stress the atmosphere exerts on the ocean surface. They have also demonstrated the capability of the frequency modulation of the backscatter to yield accurate directional wave spectra. We have demonstrated that spectra can be obtained either from images or from a rotating antenna. When these two modes are combined, our measurements indicate that it is possible to observe the complete wavenumber/frequency behavior of waves near spectral peaks. This information is valuable for assessing the importance of non-linear interactions in wave propagation, a capability that we will soon exploit in ONRís Shoaling Waves Experiment. Furthermore, our airship results have definitely shown that the conventional wisdom which said that the normalized radar cross section of the sea at a 10 degree incidence angle is relatively unaffected by the wind is incorrect. We have demonstrated both wind speed and azimuth angle dependences in such backscatter and, because of the airship, have done so without distortion of the airflow and with simultaneous meteorological measurements. Finally, these airship measurements have demonstrated that the relationship between a neutral wind speed and the measured wind speed when the atmosphere is stable is different from that usually assumed, probably because of the dependence of surface roughness on the dominant wave field.

In an attempt to generalize the results obtained to date from our various platforms, we have been working for the past few months on a multi-scale scattering model which should be applicable to the interpretation of airborne, tower, and tank data. The model builds on the integral expansion model of Fung et.al. (1992) and incorporates known properties of mean and modulated wave spectra in order to predict the cross section and Doppler spectral properties of microwave backscatter at a variety of incidence angles. The model is not yet complete but should allow the incorporation of fetch, swell, and bound wave effects into the behavior of the backscatter.

IMPACT/APPLICATION

Our results shed new light on microwave backscattering from the ocean under a variety of environmental and system conditions. Thus they are applicable to any microwave radar which senses the ocean surface. In particular, they promise to aid our understanding of the imagery of signatures of surface and subsurface vehicles, especially in the higher incidence angle region. They also indicate that a small, low-power, coherent radar system on a remotely piloted vehicle could potentially monitor ocean conditions along a hostile coastline.

TRANSITIONS

The results of this project have not yet been transitioned for operational use.

RELATED PROJECTS

This project is directly related to NASA scatterometers, such as the short-lived NSCAT. The Ku band data from the airship flights were taken simultaneously with high-quality environmental data from a platform suspended below the airship. These data have been used in an NSCAT-related project to attempt to develop better model functions and retrieval methods for scatterometers.

The project also directly applies to present attempts to obtain a global data base of ocean wave directional spectra from spaceborne SARs. Such projects have been undertaken by the Johns Hopkins University Applied Physics Laboratory and the German Max-Planck-Institut fur Meteorologie. The MPI retrevial algorithm, which incorporates methods similar to those of this project, is currently being operationally implemented to utilize ERS-2 data.

The radar system, CORAR, which was developed under this project was flown last year in NRLís Chesapeake Bay Outflow Processes Experiment and will be flown next year in ONRís Shoaling Waves Experiment.

Finally, this project has many parallels with a project run by the Office of the Secretary of Defense to investigate the microwave signatures produced by submarines. The basic understanding of microwave scattering, especially at high incidence angles, produced in this project furthers these attempts to detect submarines.

REFERENCES

Fung, A.K., Z. Li, and K.S. Chen, 1992. “Backscattering from a randomly rough dielectric surface,” *IEEE Trans. Geosci. & Remote Sensing*, 30, 356-369.

Plant, W.J. and L.M. Zurk, 1997. “Dominant wave directions and significant wave heights from SAR imagery of the ocean,” *J. Geophys. Res.*, 102(C2), 3473-3482.

Plant, W.J., 1997. “A model for microwave Doppler sea return at high incidence angles: Bragg scattering from bound, tilted waves,” *J. Geophys. Res.*, 102(C9), 21131-21146.